ExxonMobil NOx Emission Reduction Opportunities/Challenges

Texas Technology Showcase

March 17-19, 2003

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ExxonMobil NOx Emission Reduction Opportunities/Challenges

- ExxonMobil operates 1 refinery and 4 chemical plants in the HGA
- These plants contain more than 150 NOx sources
  - small heaters
  - large process heaters including conventional and high temperature
  - boilers, cogeneration gas turbines, IC engines
  - process sources including primarily FCCUs
- The large number and variety of sources provides numerous challenges to attain compliance with stringent emission reduction requirements in a relatively short time span
  - requires rapid identification/development of cost effective technology
  - requires extensive planning, coordination and implementation effort to minimize disruption of plant operations

Large Variety of NOx Sources

- Fired heater sources have many variations…few identical
  - cabin, VC, box, one-of-a-kind
  - vertical/horizontal firing
  - round/flat flame burners
  - natural draft/forced draft
  - ambient/preheated air
  - RBG/RBG+LBG
  - low/normal/high process temperature applications
- Boilers include both conventional and CO boilers
- Cogeneration GTGs include multiple size classifications
- FCCUs include two different types each posing unique challenges

Emissions and Equipment Demographics

- Number of Sources
  - Small Heaters, 34%
  - Large Heaters, 45%
  - Gas Turbines, 9%
  - Boilers, 6%
  - IC Engines, 5%
  - FCCUs, 1%
- Estimated Emissions
  - Small Heaters, 8%
  - Large Heaters, 36%
  - Gas Turbines, 28%
  - Boilers, 9%
  - IC Engines, 4%
  - FCCUs, 15%

▶ Cost effectiveness vs NOx reduction seriatim developed to select appropriate sources to achieve required NOx reduction and meet TCEQ milestones

Steps to Successful Technology Application

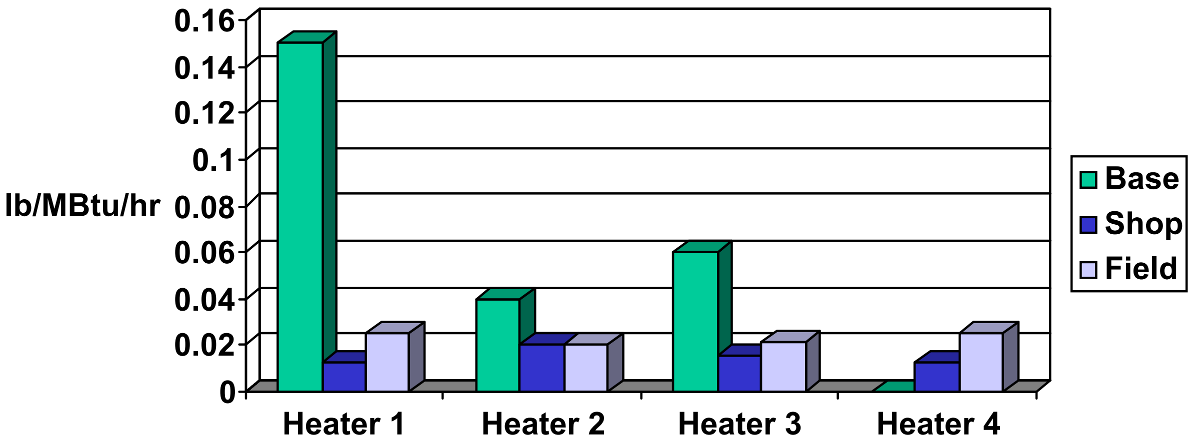
- Step 1-Develop comprehensive physical, operating data and emissions data for all sources
  - Update or prepare required drawings, verify operating data
- Step 2-Assess technology needs to achieve TCEQ guideline
  - Screen most likely technology to satisfy needs of each source
  - Very few “identical” sources
- Step 3-Apply or develop most appropriate cost-effective technology
  - Develop ULNBs for <0.02 lb/MBtu NOx
  - Apply existing post combustion controls where necessary
  - Assess/develop emerging technology
- Step 4-Resolve technology application peripheral issues
  - fuel system
  - equipment access
  - operating constraints

Technology Development Overview

- **Process heaters**
  - Shop tested over 20 different burners with leading burner suppliers.....nominally <0.020 lb/MBtu NOx
  - Retrofitted ULNBs to new and retrofit heaters.....0.02-0.025 lb/MBtu NOx
- **High temperature heaters**
  - ExxonMobil proprietary burner shop tested at 0.035 lb/Mbtu (air preheat)
  - Field test of ExxonMobil burner planned in 1Q03 (ambient and air preheat)
- **Boilers**
  - Vendor tested ULNB at 0.015 lb/MBtu for utility boilers
- **FCCUs**
  - Field tested optimized FCCU operation
  - Vendor tested ULNB technology for CO Boilers
  - Completed WGS additive field and pilot plant testing
  - Completed TDN field tests
  - Field testing low-NOx regenerator additives and CO promoters
  - Evaluating exhaust gas controls including SCR, LoTOx
- **GTGs**
  - GE lean head liners installed in Frame 5
  - SCR required to meet TCEQ emission factor

Fired Heater Ultra Low NOx Burners

- Vendor programs.....tested 20 different burners
- Field programs.....installed ULNBs in three retrofit and one new heater
  - Heater 1, ND, RBG only, ambient air, cabin
  - Heater 2, FD, RBG / LBG, moderate AP, cabin
  - Heater 3, ND, RBG only, ambient air, VC
  - Heater 4, ND, RBG only, ambient air, VC
- Performance comparisons

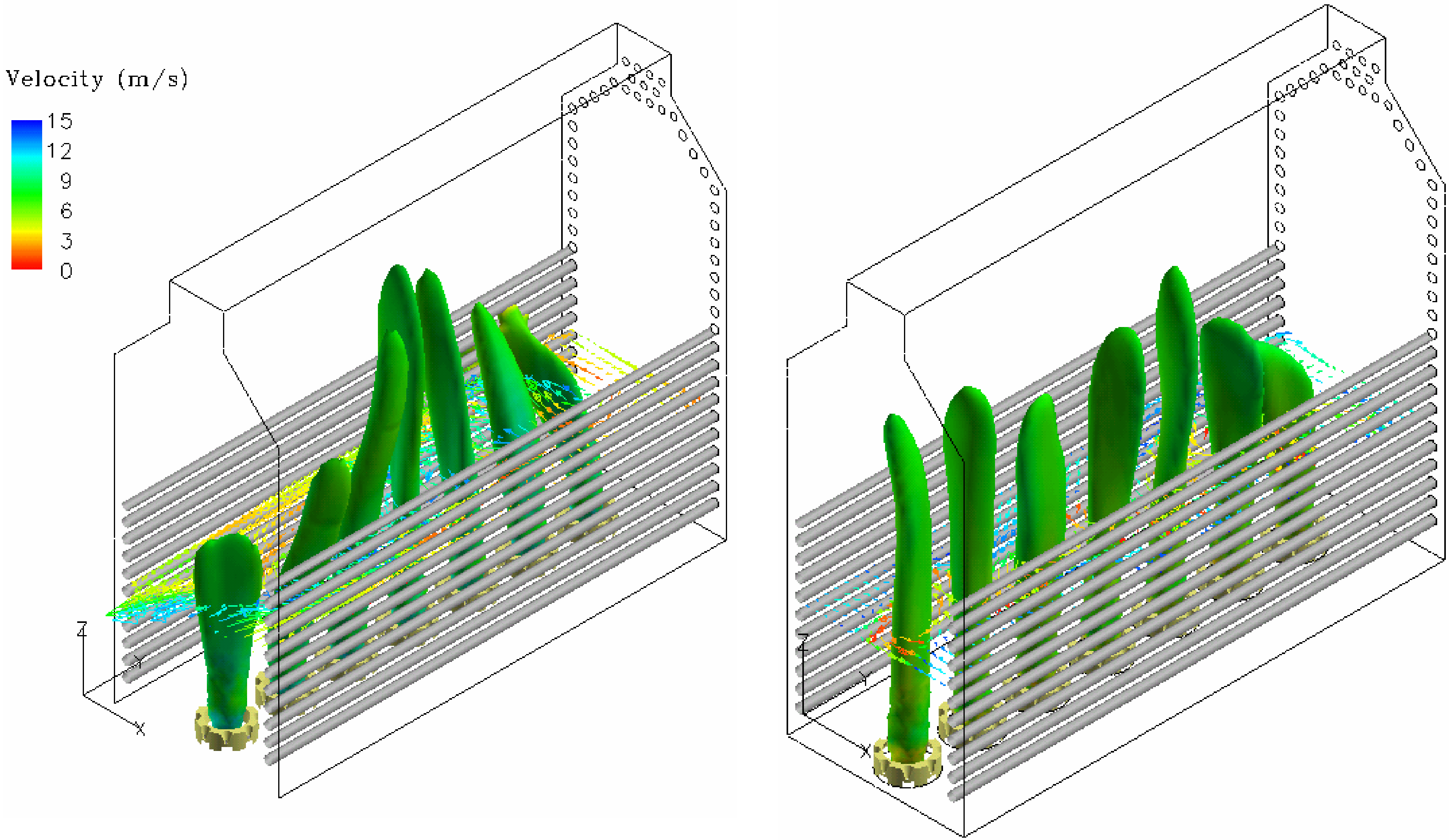


Refinery Demonstration Heater

- Demonstration conducted in association with consortium headed by DOE and ExxonMobil was a member
- Demonstration furnace was an atmospheric pipestill furnace at ExxonMobil's Baytown Texas refinery
  - horizontal tube cabin configuration
  - 140 MBtu/hr maximum firing rate
  - fuel gas composition varies from high methane to high hydrogen
- A computational fluid dynamics (CFD) model was utilized to predict radiant section performance and thereby identify potential problems
  - Flow patterns
  - Flame geometry

DEMONSTRATION HEATER

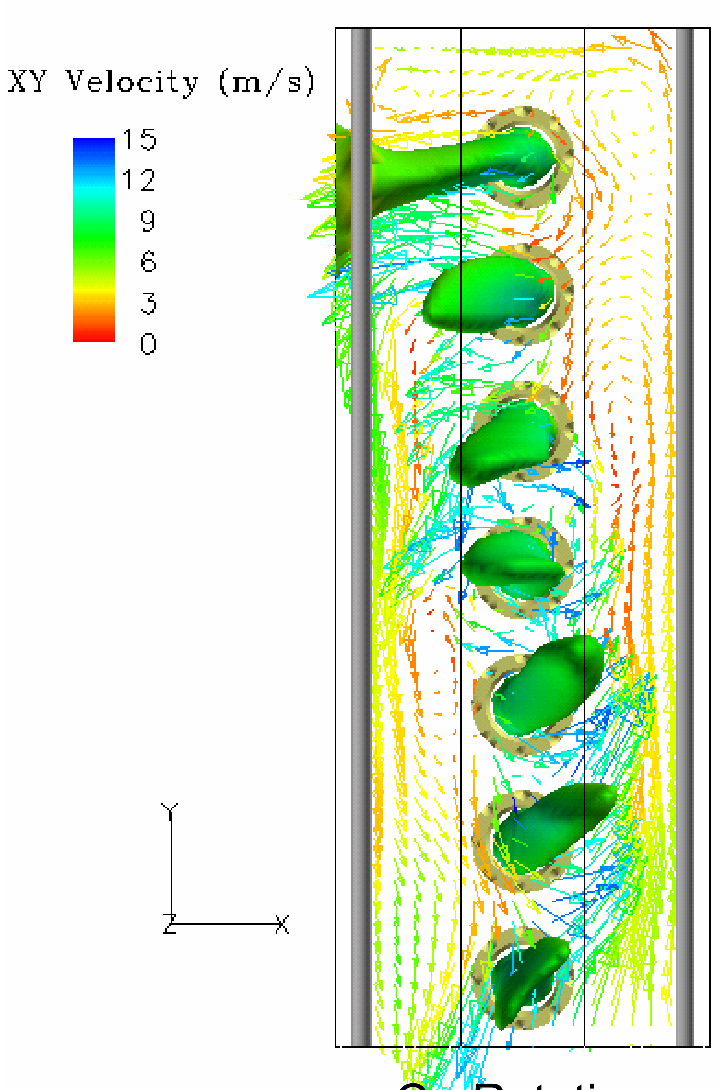
BURNER DEMONSTRATION CFD MODELING



Co-Rotating

Counter-Rotating

BURNER DEMONSTRATION CFD MODELING



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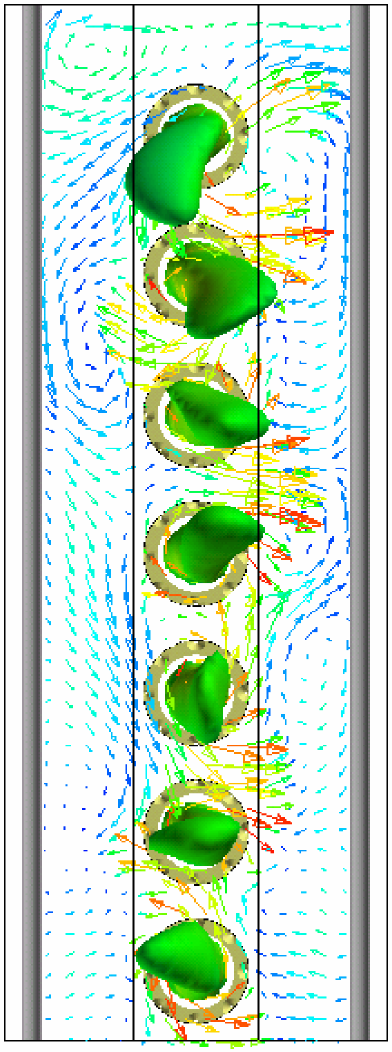
Counter-Rotating

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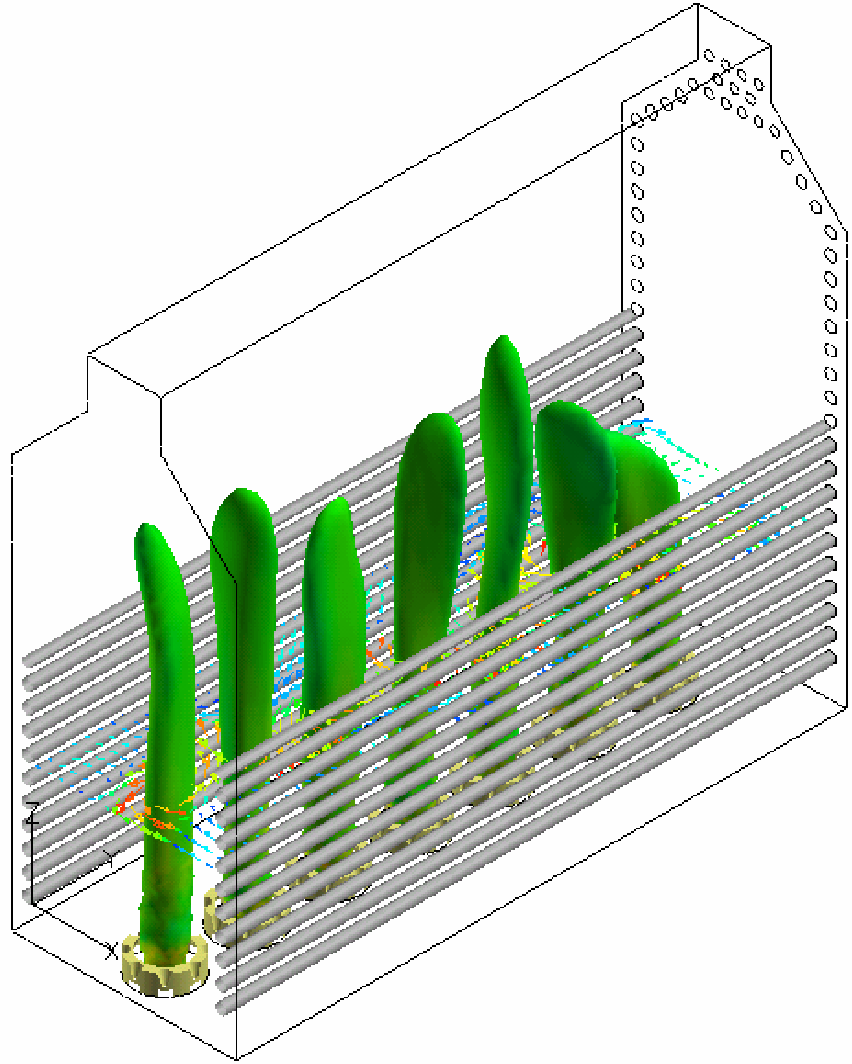
IMPLEMENTATION/STARTUP SUCCESSFUL

- A set of 14 field test burners were installed for the retrofit demonstration replacing 18 original burners
- The fired heater was started up in May 2001.
  - Flame geometry and flow patterns are consistent with the CFD predictions
  - Heat Flux profile meets specifications.
  - Burner stability good when fuel composition is within specifications; however pulsation experienced when methane content exceeds 85%.
  - Initial NO_x levels higher than anticipated at 0.030 lb/MBtu
  - A new flame stabilizer and gas tips were developed to enhance stability and lower NO_x to ~0.025 lb/MBtu

BURNER DEMONSTRATION FINAL CFD



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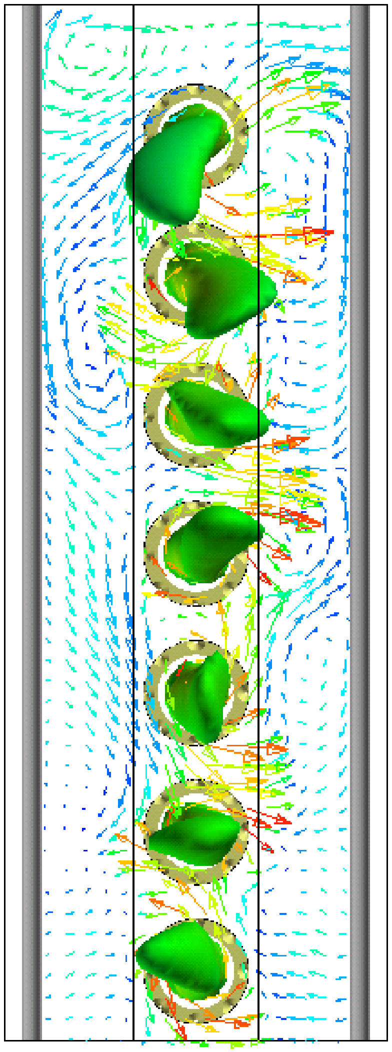

Counter-Rotating

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BURNER FLAMES MATCH CFD PREDICTION

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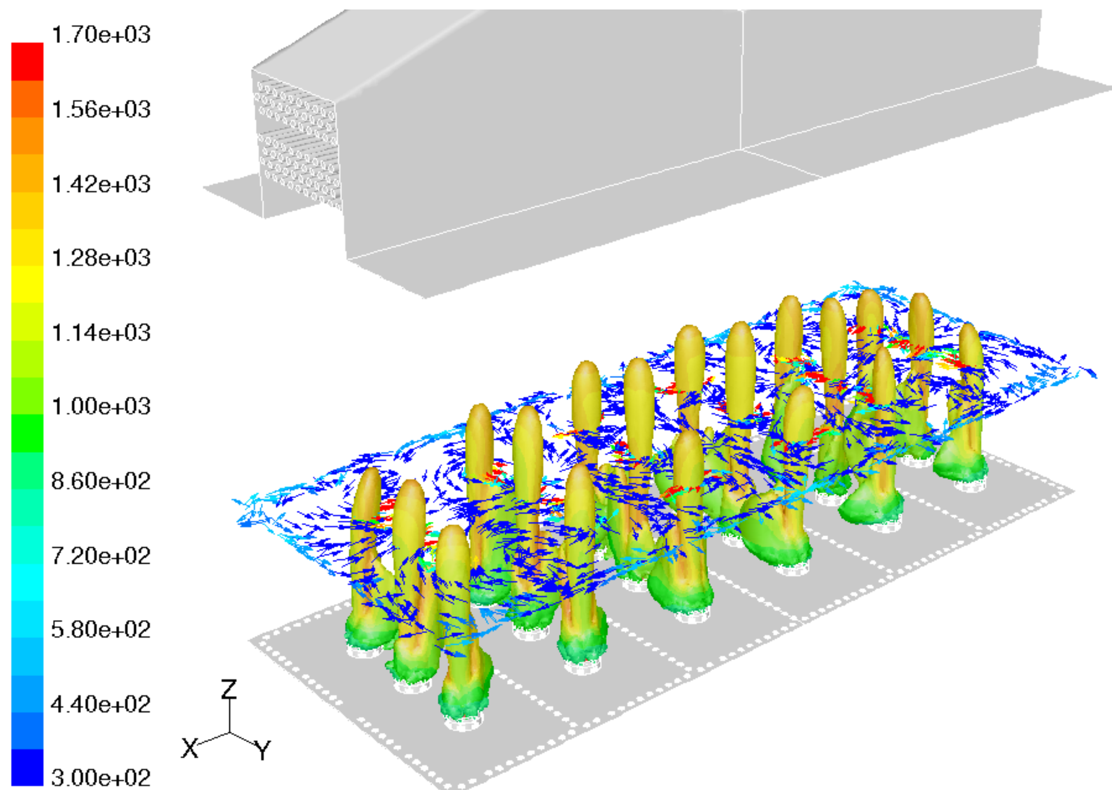
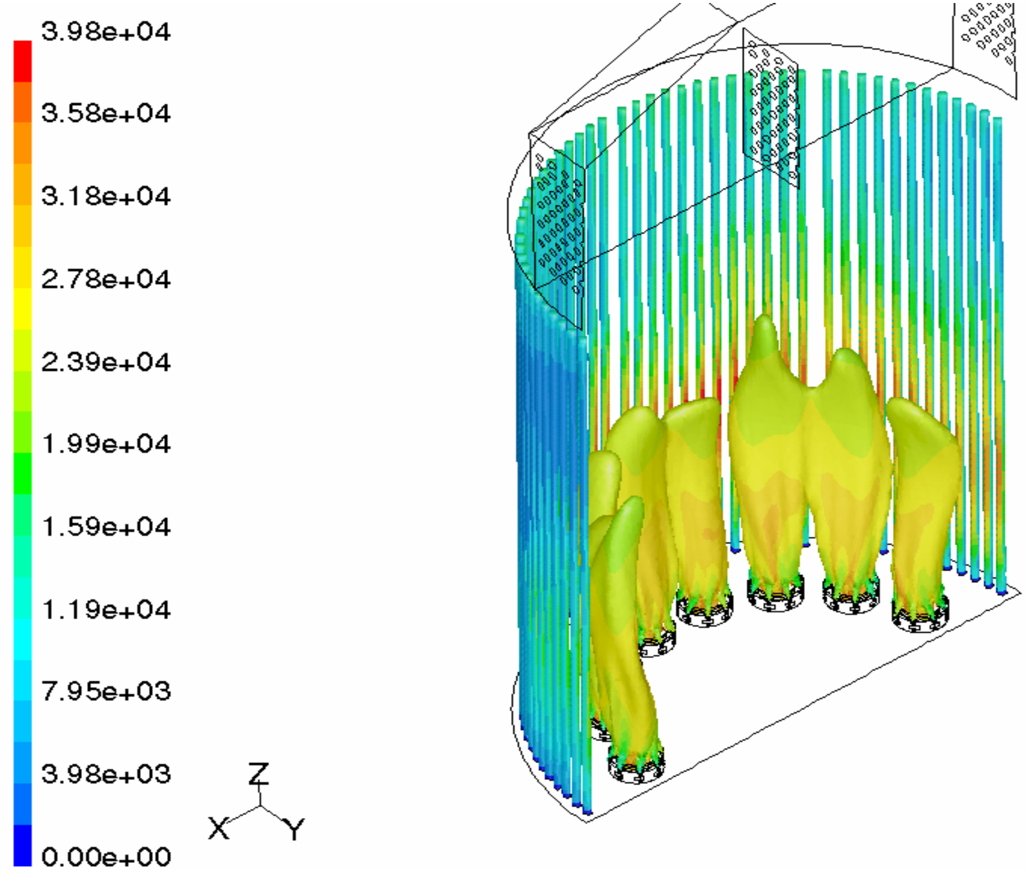
CFD Examples of other ULNB installations

LARGE FD VERTICAL TUBE BOX PROCESS HEATER W/AP, RBG/LBG



Contours of Static Temperature (k) Sep 17, 2001
FLUENT 5.5 (3d, segregated, spe8, rke)

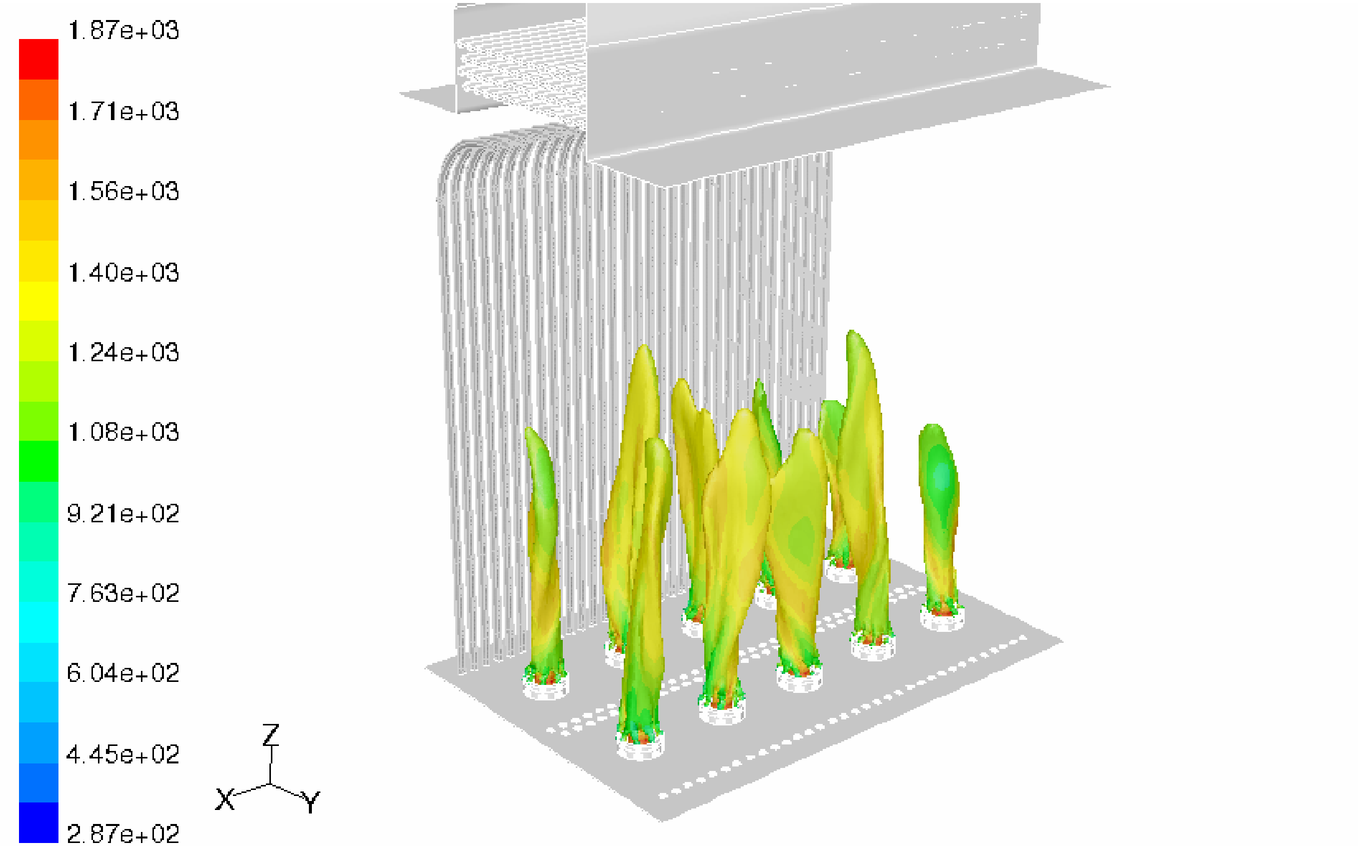
LARGE FD VC PROCESS HEATER W/AP, RBG/LBG



Contours of tube-wall-flux

Jan 28, 2002
FLUENT 5.5 (3d, segregated, spe8, rke)

LARGE FD HOOP TUBE HEATER W/AP, RBG/LBG



Contours of Static Temperature (k)

Sep 26, 2001
FLUENT 5.5 (3d, segregated, spe8, rke)

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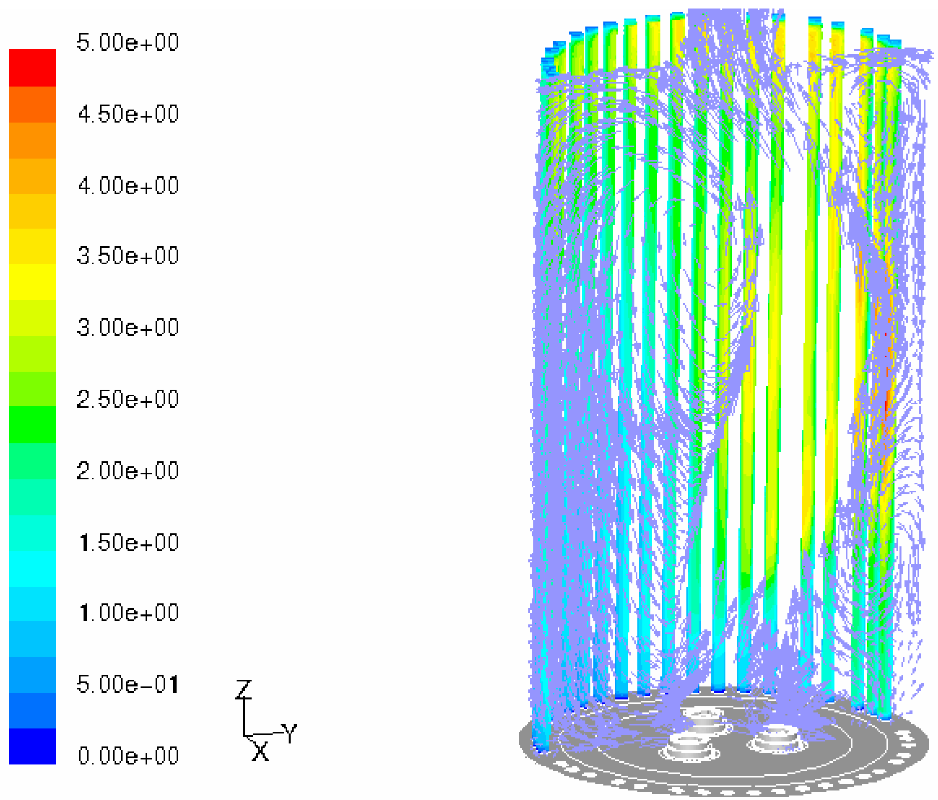
SMALL ND VC HEATER, AMBIENT, RBG



Velocity Vectors Colored By Velocity Magnitude (m/s) Jun 17, 2002
FLUENT 6.0 (3d, segregated, spe8, rke)

Large recirculation zones cause foreshortening of flames.

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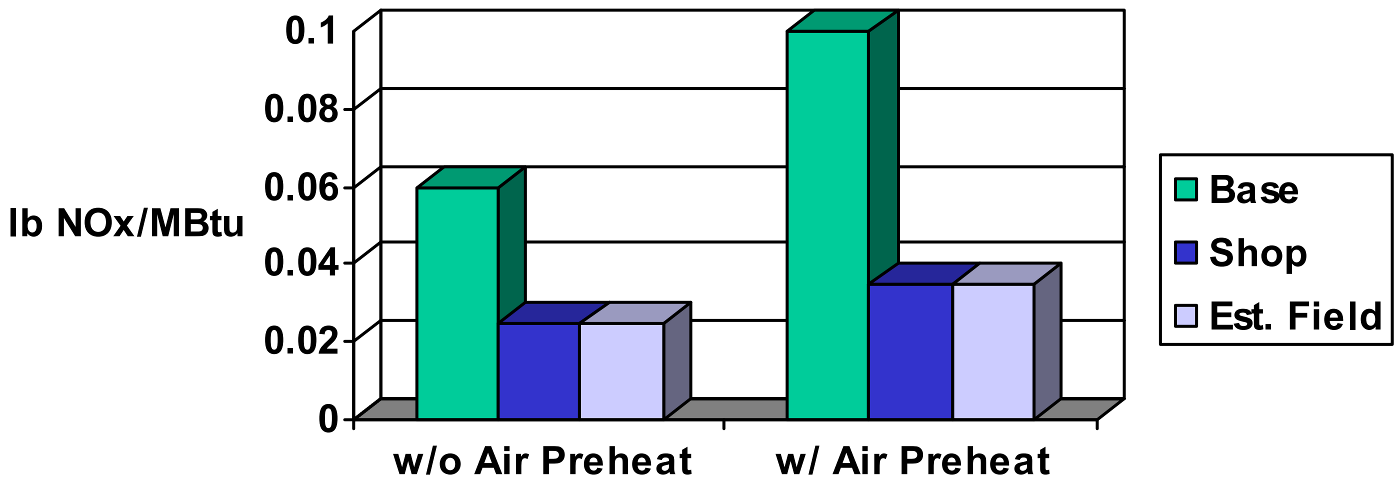
High Temperature Heater ULNB

- Vendor programs
  - ExxonMobil proprietary burner shop tested with air preheat at 0.035 lb/MBtu with excellent stability
- Performance comparisons

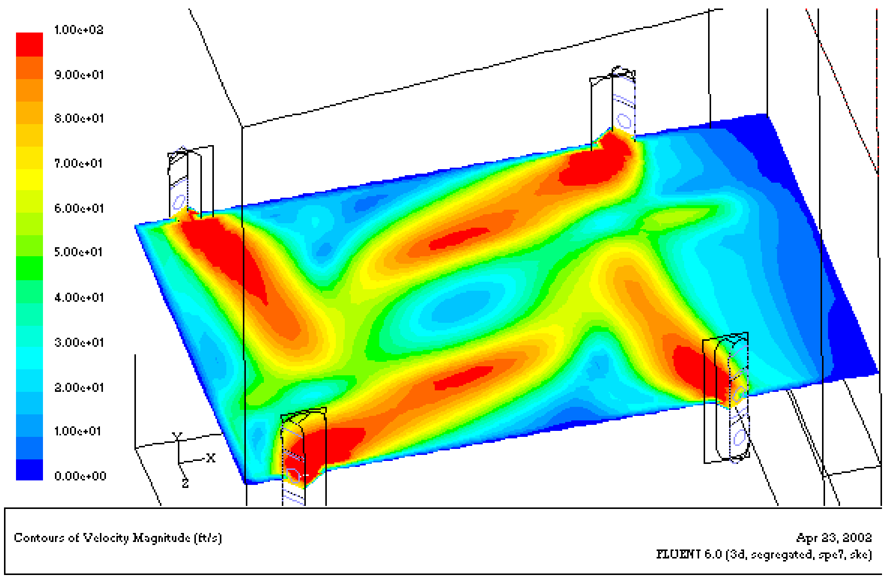


Power Boilers

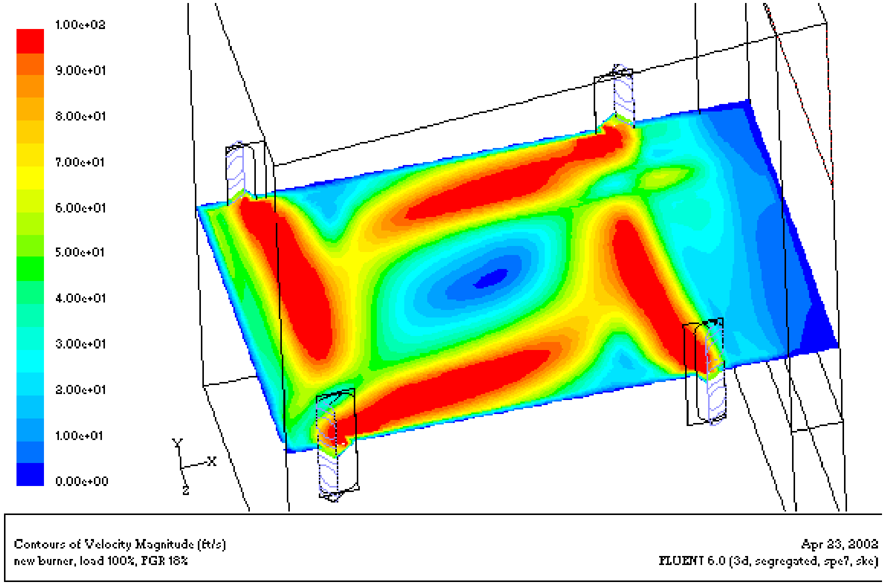
- Power boilers
  - Boilers are tangential fired (two levels), moderate AP, RBG and waste fuel
  - Design conditions:
    - steam flow-320,000 lb/hr
    - pressure-1500 psig
    - temperature-915 F
- Burners
  - Include reconfigured windbox/burner gun location
  - Burner guns designed for “attached” flames
  - Flue gas recirculation 15%-25%
  - Air distribution improved to each corner and within each windbox to enable low excess O2 operation

VELOCITY MAGNITUDE AT BURNER LEVEL, EXISTING AND NEW

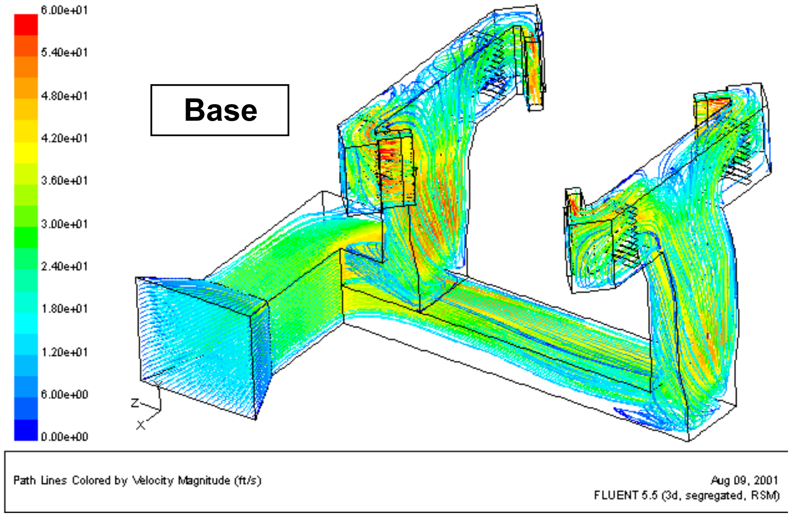
Existing

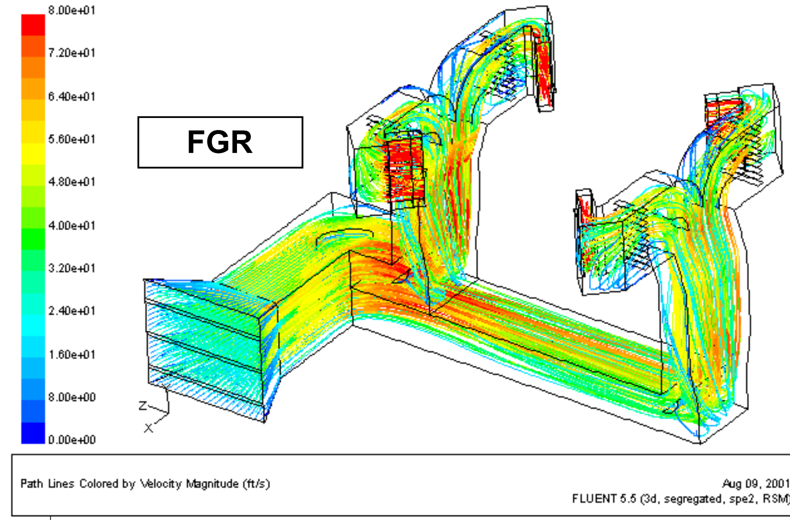


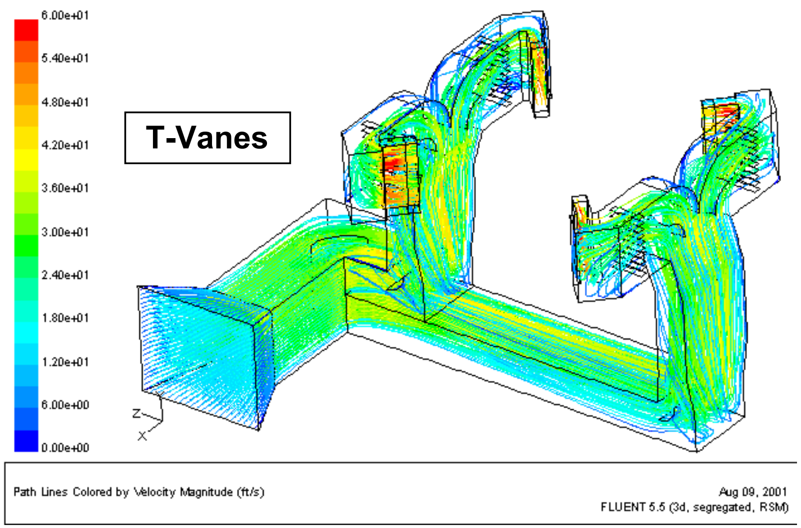
New

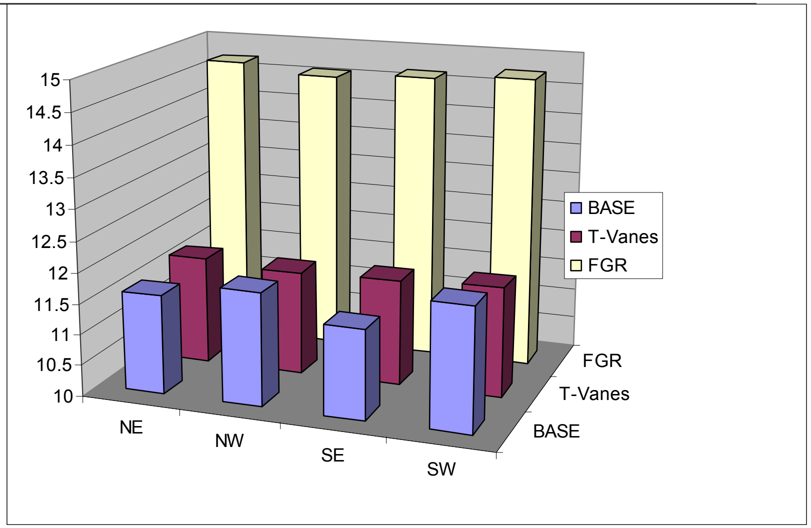


AIR DUCTING MALDISTRIBUTION REDUCED WITH ADDITION OF BAFFLES, TURNING VANES









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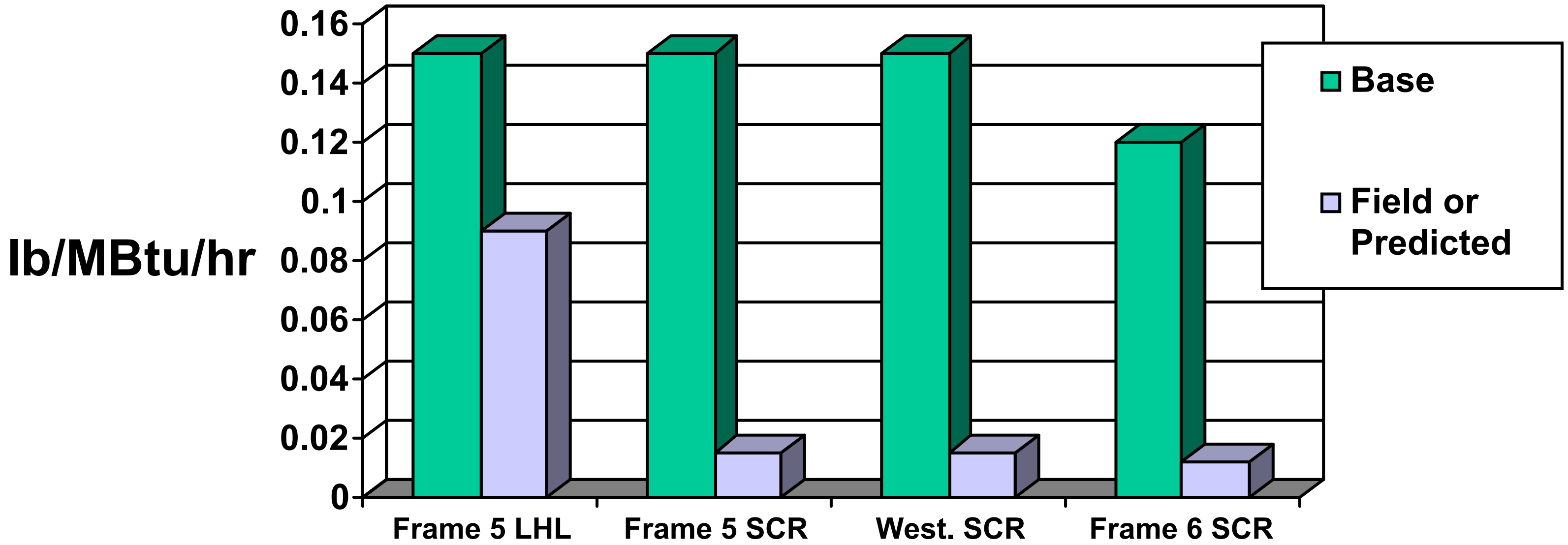
Gas Turbines

- Plan to install LHL and SCR in most GTGs
- Performance



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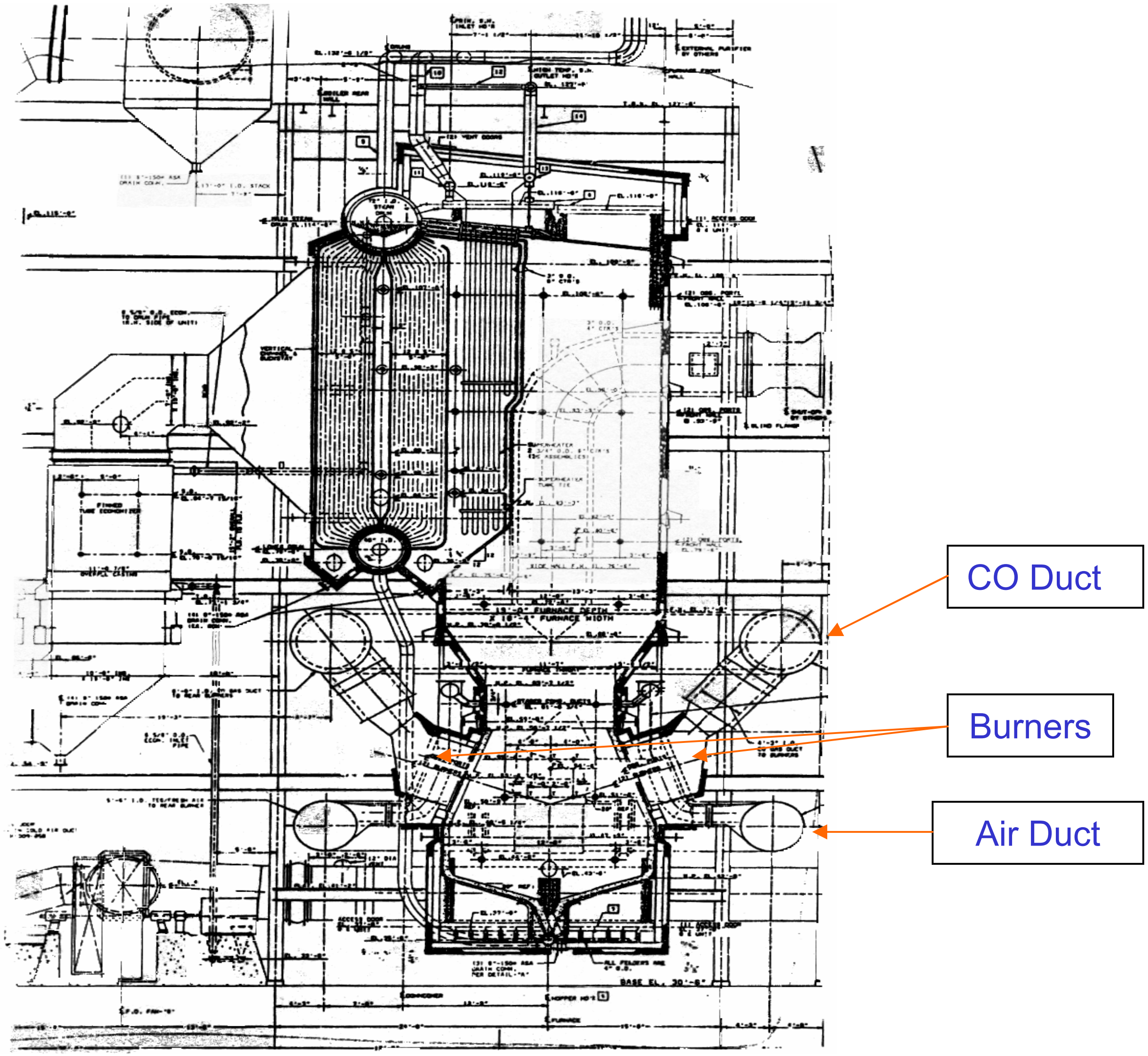
FCCU NOx Reduction

- Involves multiple technologies including operational changes, combustion and post combustion techniques
- Strategy includes
  - utilization of existing equipment as reaction chamber
  - multiple reduction steps each with different technology
  - minimization of overall cost through optimization of investment and operating cost
- Technologies under consideration include
  - optimized low NOx operation
  - low NOx CO promoter and/or low NOx additive
  - regenerator overhead line TDN
  - retrofit CO boilers with LNBs
  - WGS additive
  - SCR
  - LoTOx

CO Boiler LNBs

- Includes two types of boilers
  - tangential fired (2), SG 501 A/B
  - opposed wall fired, SG 501 C
- Opposed wall fired boiler has twice capacity of each tangential fired boiler, receives one-half of regenerator overhead off-gas
- Boilers have capability of maintaining capacity with fuel gas firing alone (no regenerator off-gas)
- Combined stream from 3 boilers is sent to a WGS

C BOILER GENERAL ARRANGEMENT



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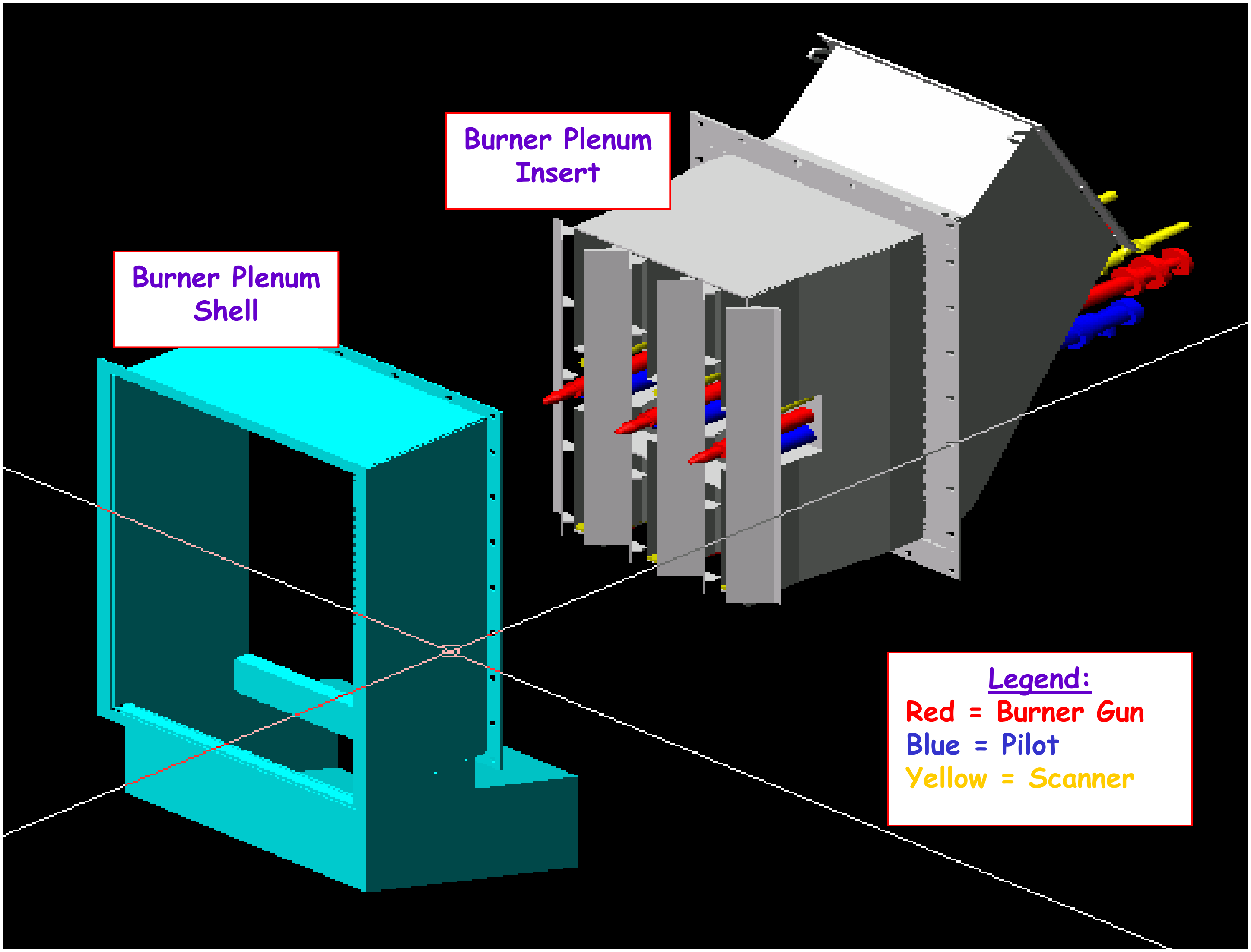
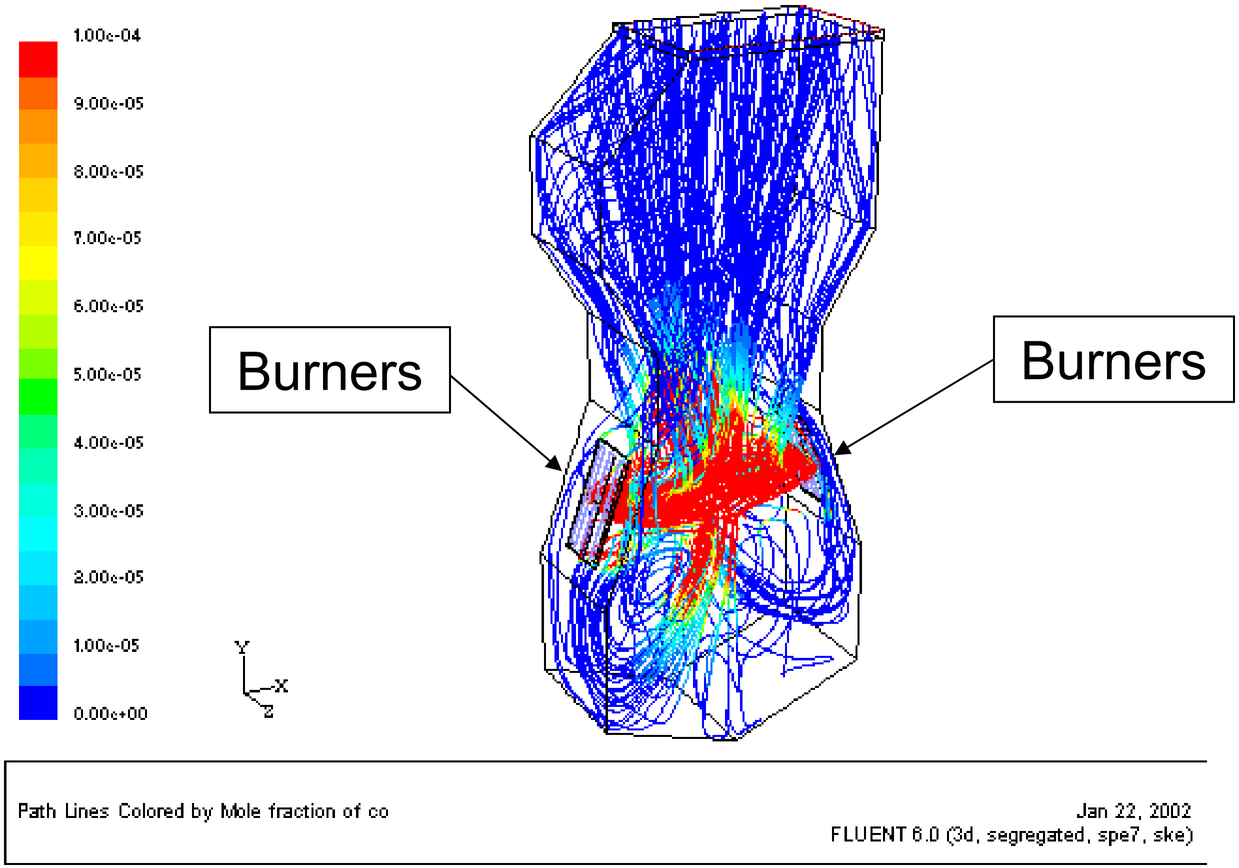
NEW BURNER FOR C BOILER

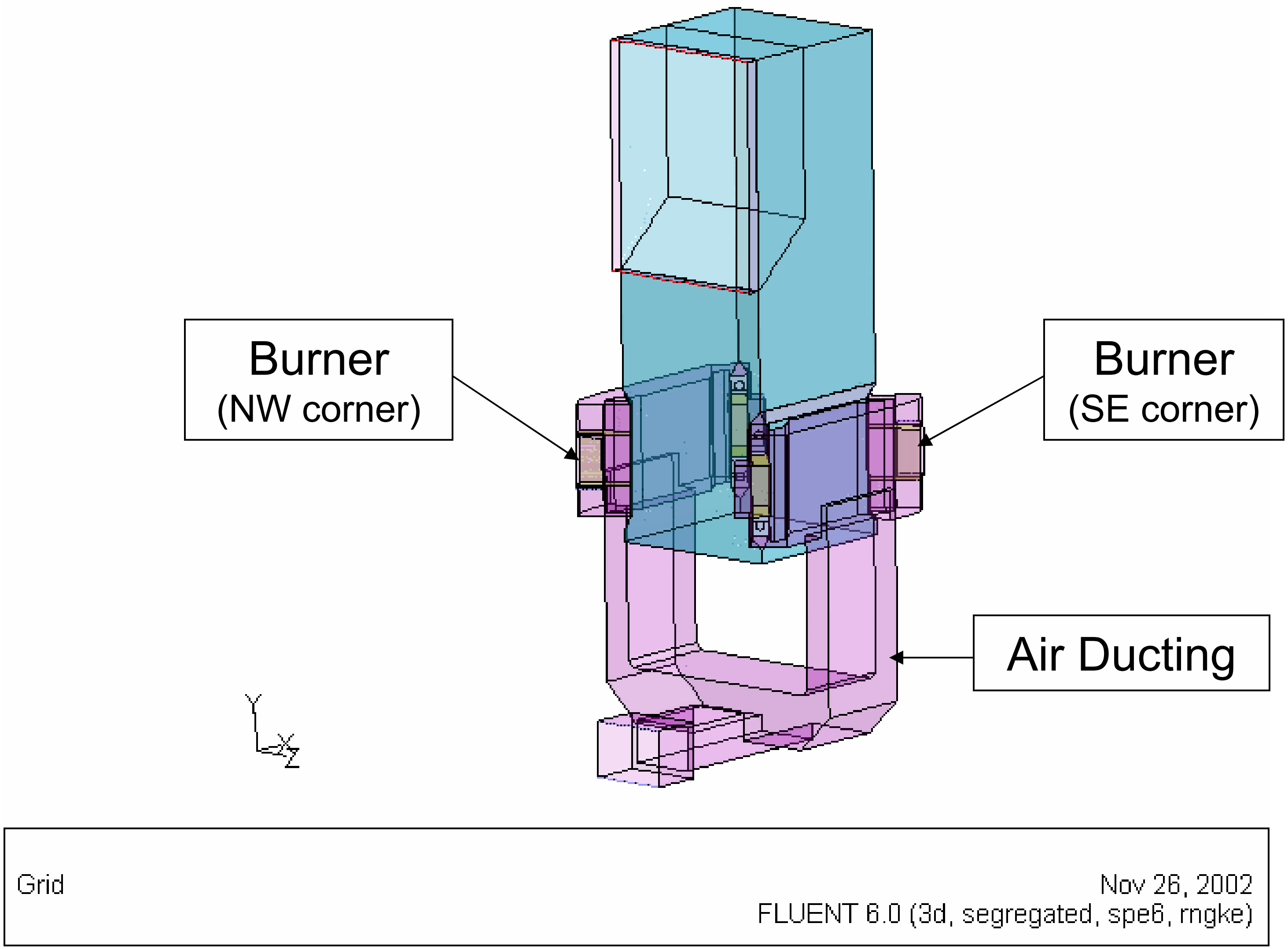


CFD MODELING RESULTS RE CO BURNOUT IN C BOILER

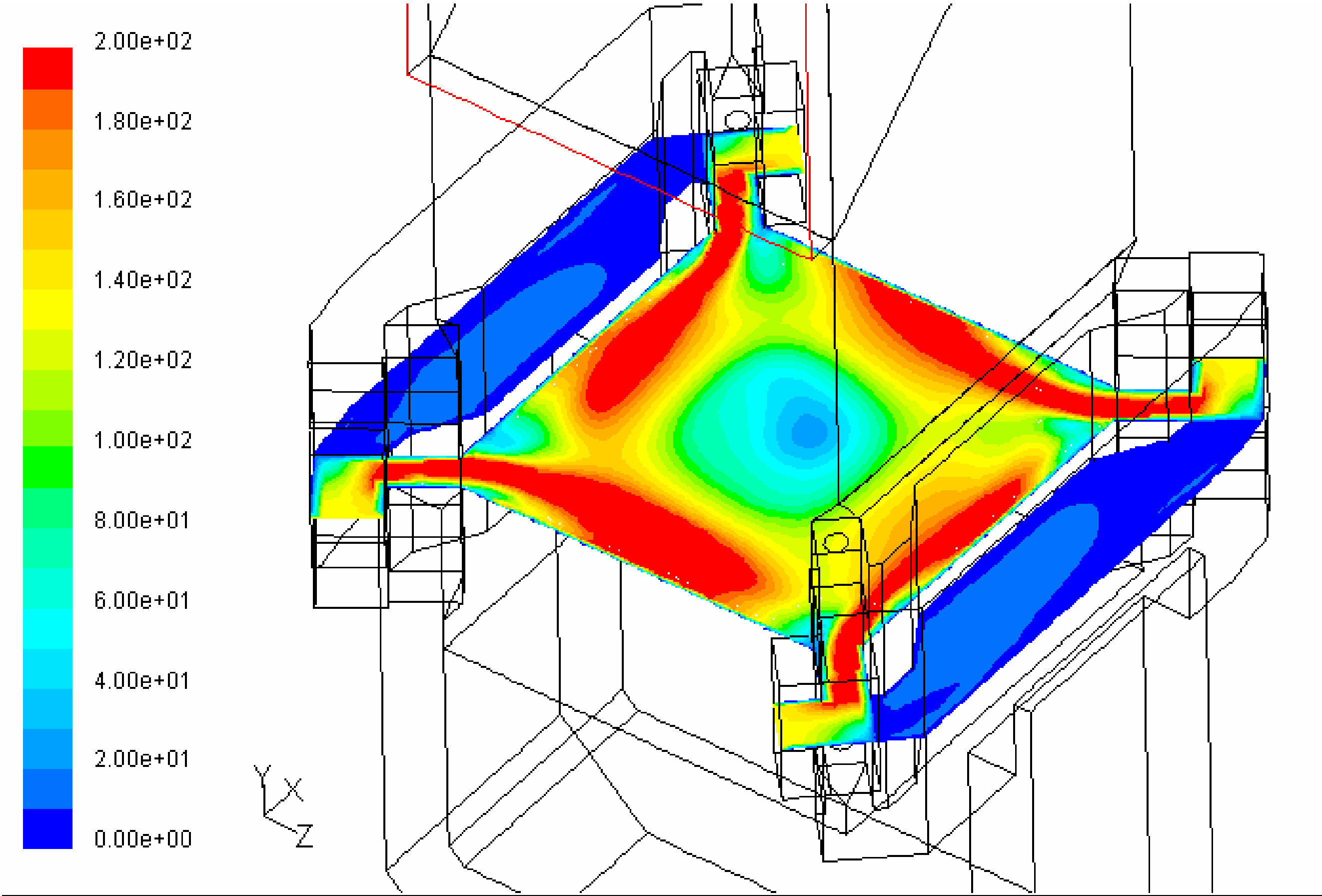


<u>SG 501C-CO Burnout Occurs Within Firebox</u>

OVERALL GEOMETRY OF A/B DUCTING AND BOILER FIREBOX



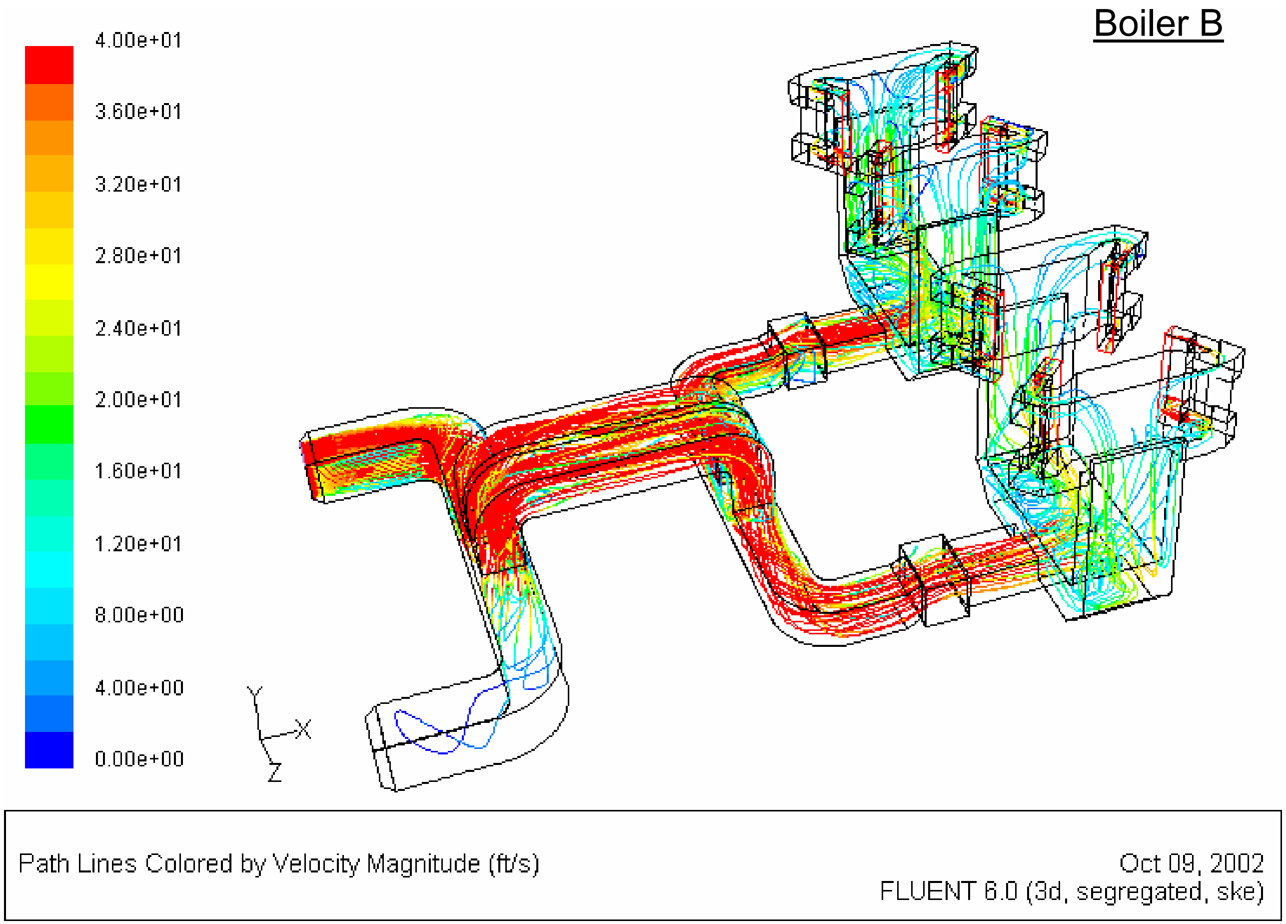
A/B VELOCITY CONTOURS AT CO PORT LEVEL



Contours of Velocity Magnitude (ft/s)

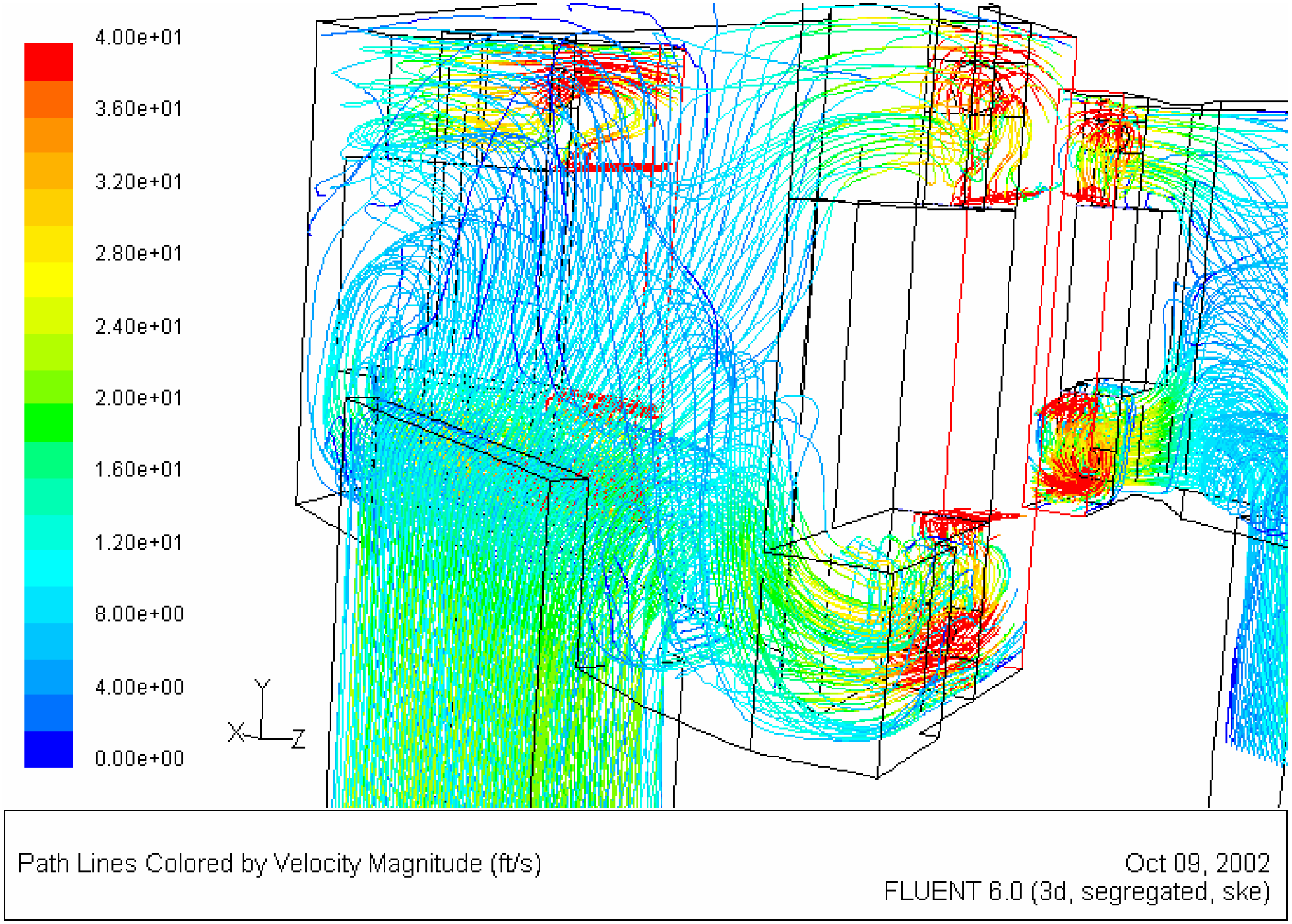
Nov 26, 2002
FLUENT 6.0 (3d, segregated, spe6, rngke)

A/B AIR DUCTING FLOW DISTRIBUTION



SG 501 A/B-Air Split Evenly Between A and B

A/B COMBUSTION AIR DISTRIBUTION IN WINDBOXES



SG 501A/B-Windbox Requires Turning Vanes To Equalize Air Distribution

Conclusions

- Goal is to meet the HGA Ozone SIP in the most economical way while maintaining throughput and service factor
- Challenges/opportunities are numerous and varied requiring application of known technology as well as rapid development of new technology
- Technology development must be progressed simultaneous with implementation plans
- Investment cost can be minimized by judicious selection of sources/technologies
- ExxonMobil is on target to comply with TCEQ requirements

Questions?